Coral reef fish stock assessments: beyond data-poor




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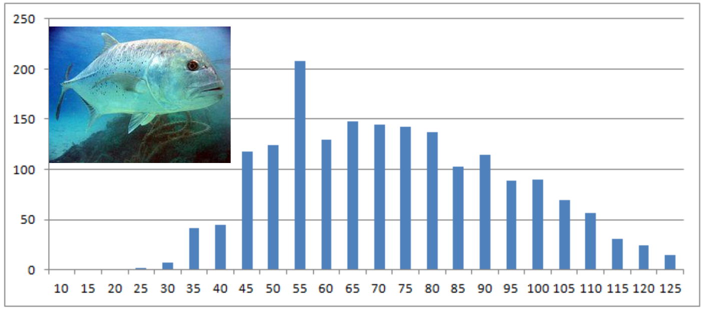
Stock assessment program

Assessing coral reef fish stocks

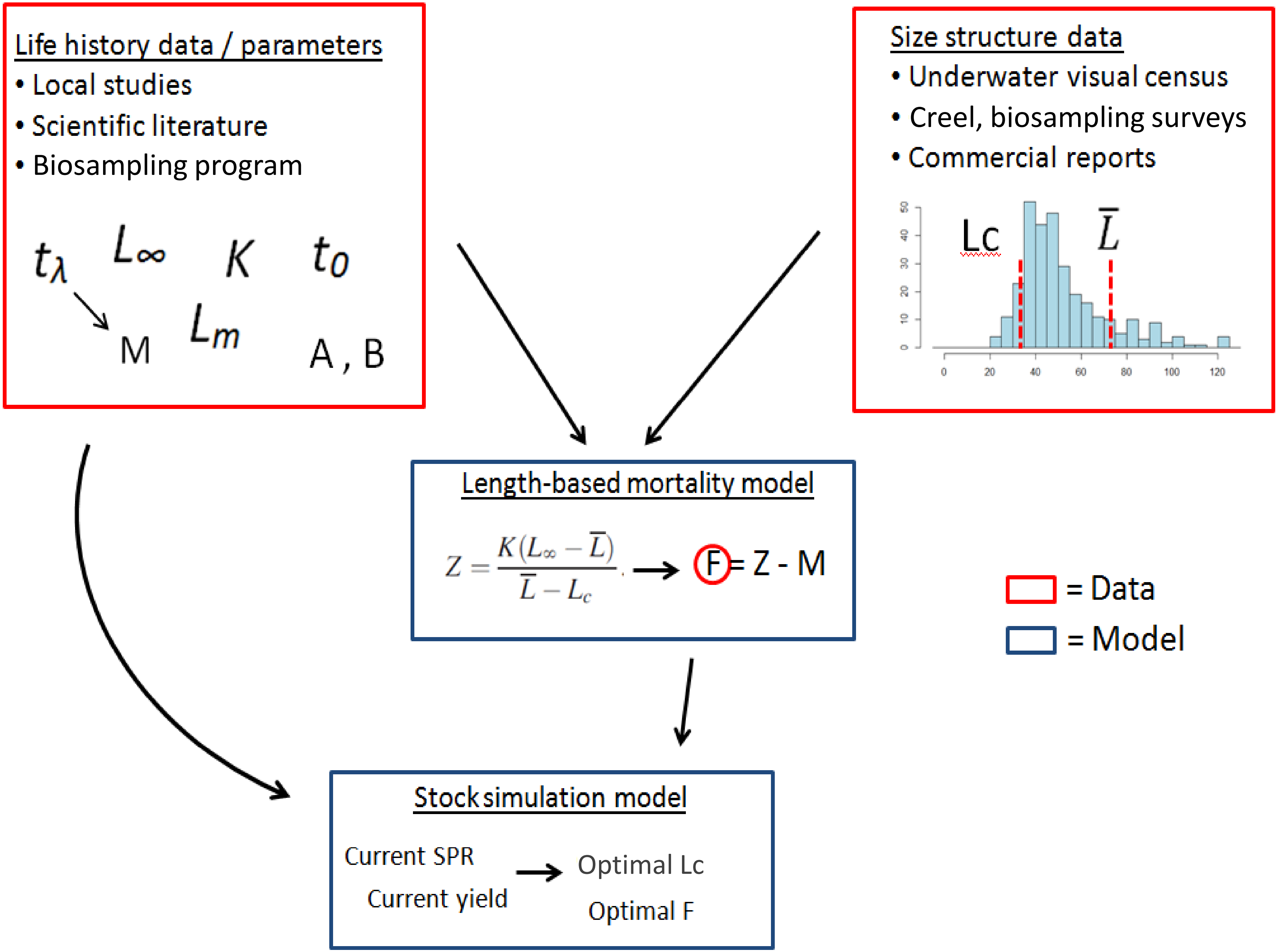
- Problems
  - Lots of species (>100 targeted species)
  - Spatially diffuse landings, hard to obtain catch data
  - Hard to obtain abundance estimates
  - Few life history studies

Available data

- Abundance at size
- Life history information



Source	Hawaii	American Samoa	Mariana
Diver surveys	X	X	X
Marine Recreational Information Program (MRIP)	X		
Local creel surveys		X	X
Biosampling		X	X
Commercial trip reports	X		


Life history data / parameters
• Local studies
• Scientific literature
• Biosampling program
t_λ
L_∞
K
t_0
M
L_m
A , B
Size structure data
• Underwater visual census
• Creel, biosampling surveys
• Commercial reports
Lc
$\bar{L}$
0
20
40
60
80
100
120
Length-based mortality model
$Z = \frac{K(L_\infty - \bar{L})}{\bar{L} - L_c}$
F = Z - M
= Data
= Model
Stock simulation model
Current SPR
Current yield
Optimal Lc
Optimal F

Beverton-Holt total mortality (Z) estimator

$$L_t = L_\infty(1 - e^{-K(t-t_0)})$$

$$\overline{L} = \frac{\int_{t_c}^{t_\infty} F_t \cdot L_t \cdot N_t \cdot dt}{\int_{t_c}^{t_\infty} F_t \cdot N_t \cdot dt} \rightarrow Z = \frac{K \cdot (L_\infty - \overline{L})}{(\overline{L} - L_c)}$$

F = Z - M

$$N_{t+\Delta t} = N_t e^{-(M+F)\Delta t}$$

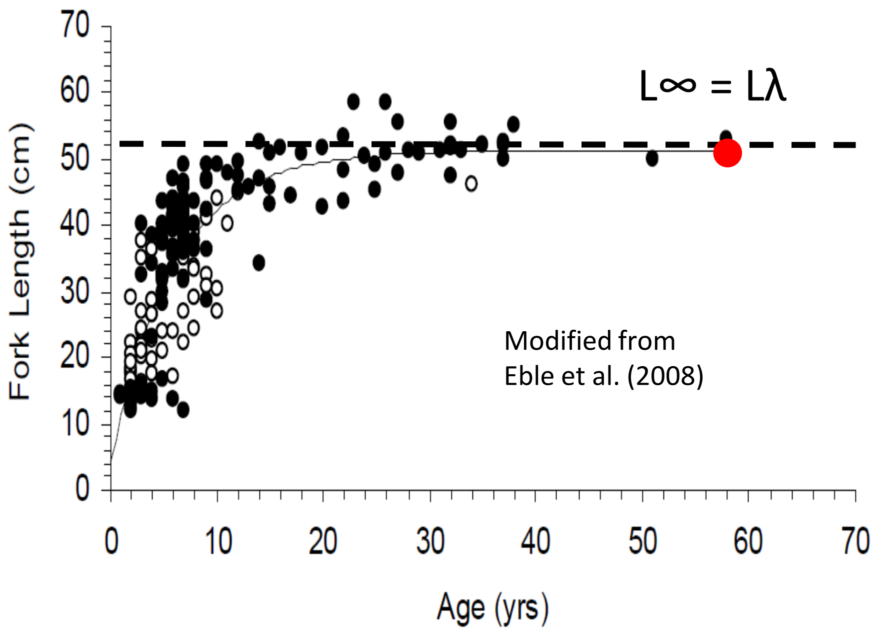
Ehrhardt and Ault total mortality (Z) estimator

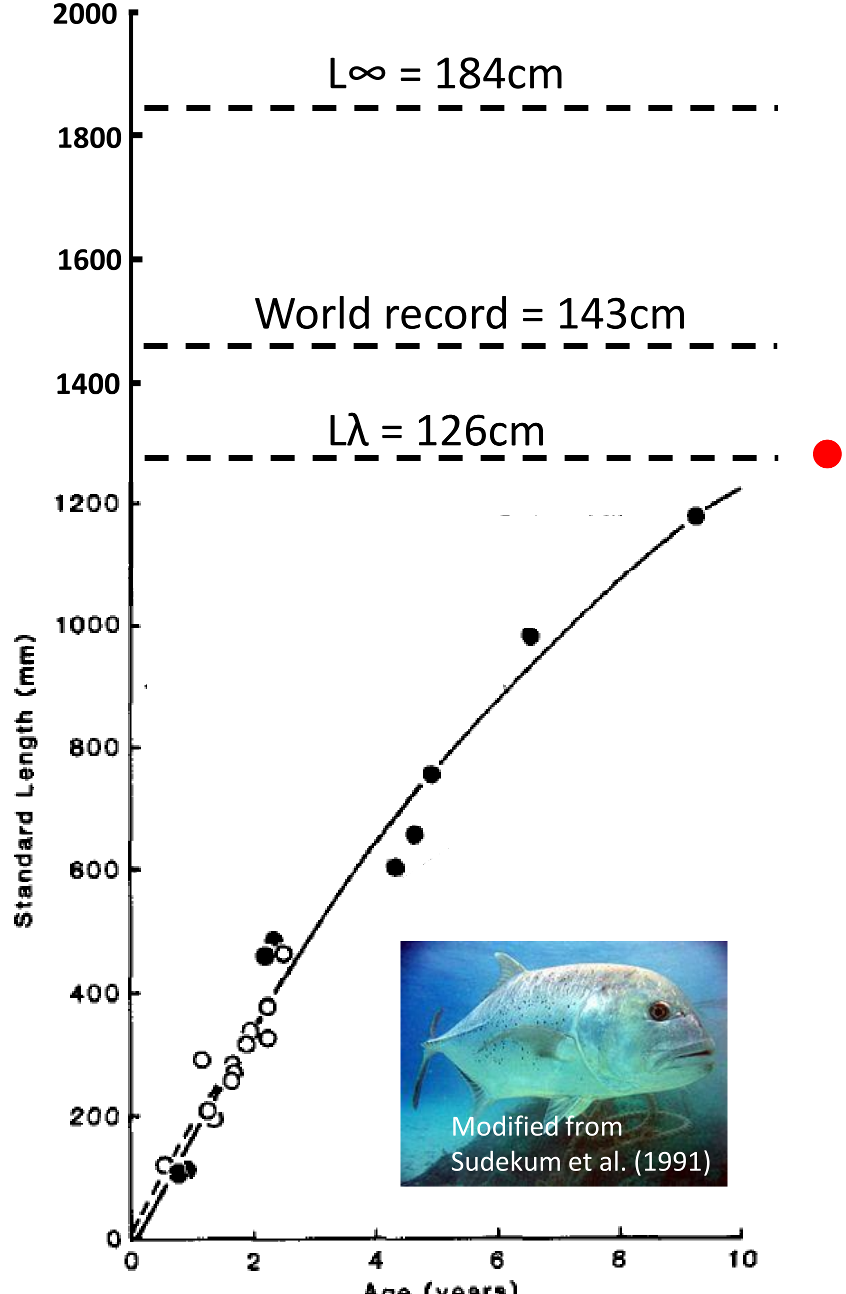
Fish don't live for ever

$$\overline{L} = \frac{\int_{t_c}^{t_\lambda} F_t \cdot L_t \cdot N_t \cdot dt}{\int_{t_c}^{t_\lambda} F_t \cdot N_t \cdot dt} \quad \rightarrow \quad \left(\frac{L_\infty - L_\lambda}{L_\infty - L_c}\right)^{Z/k} = \frac{Z\left(L_c - \overline{L}\right) + K\left(L_\infty - \overline{L}\right)}{Z\left(L_\lambda - \overline{L}\right) + K\left(L_\infty - \overline{L}\right)}$$

$t\lambda$ = Mean length at maximum age

Caranx ignobilis – “ulua” or giant trevally

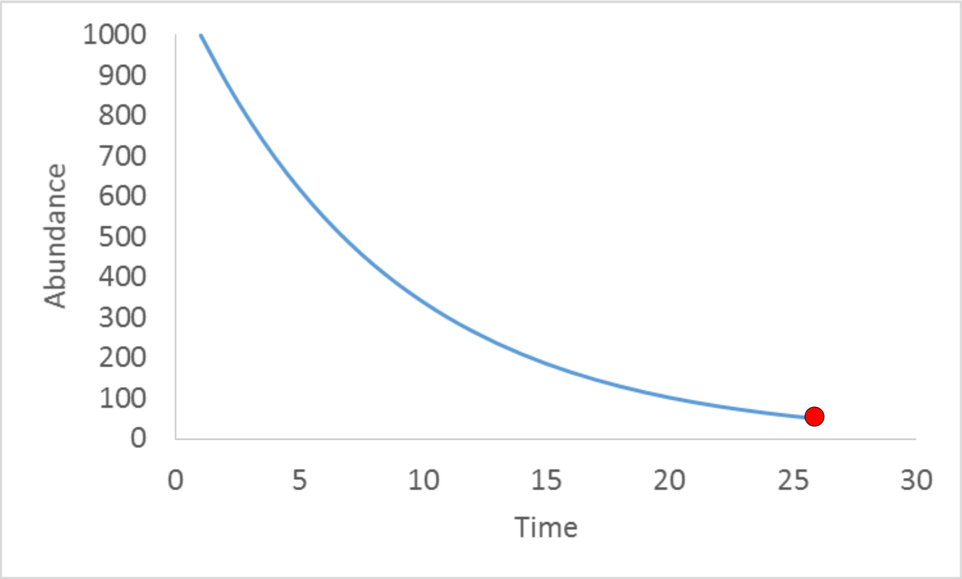




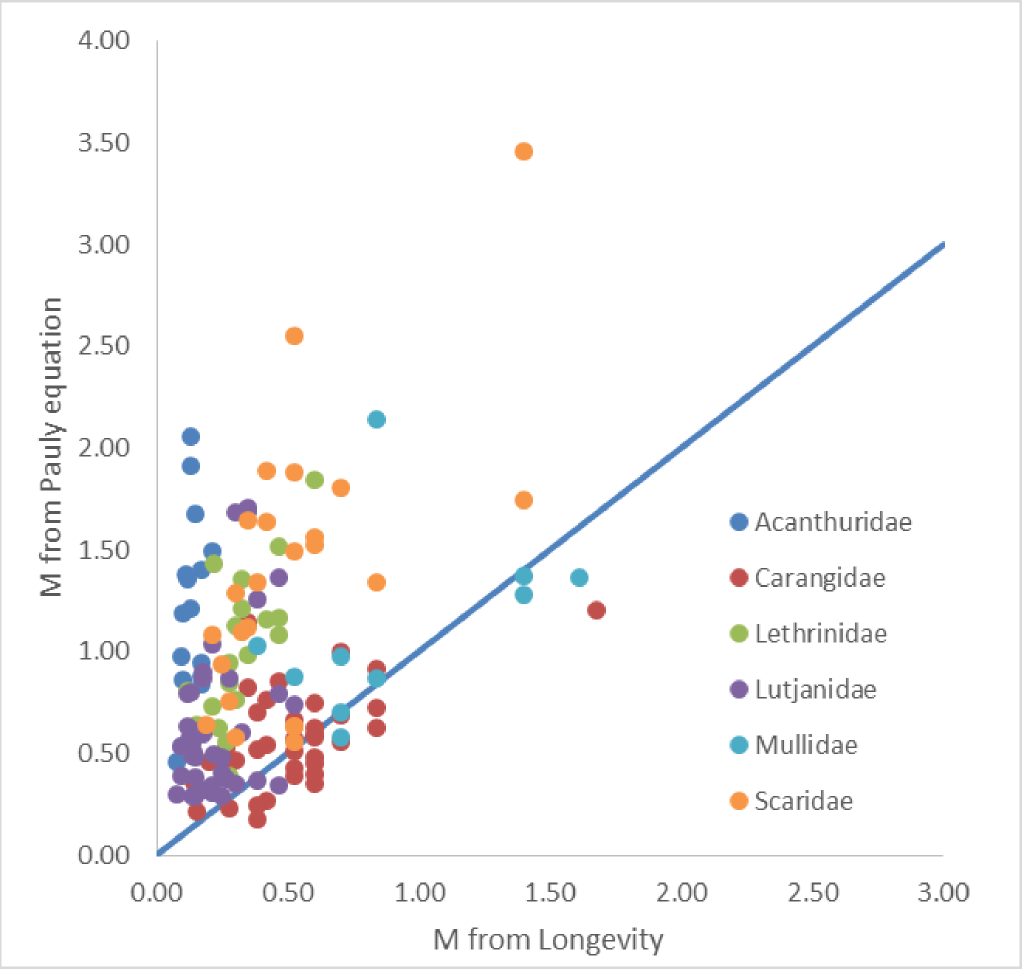
Natural mortality

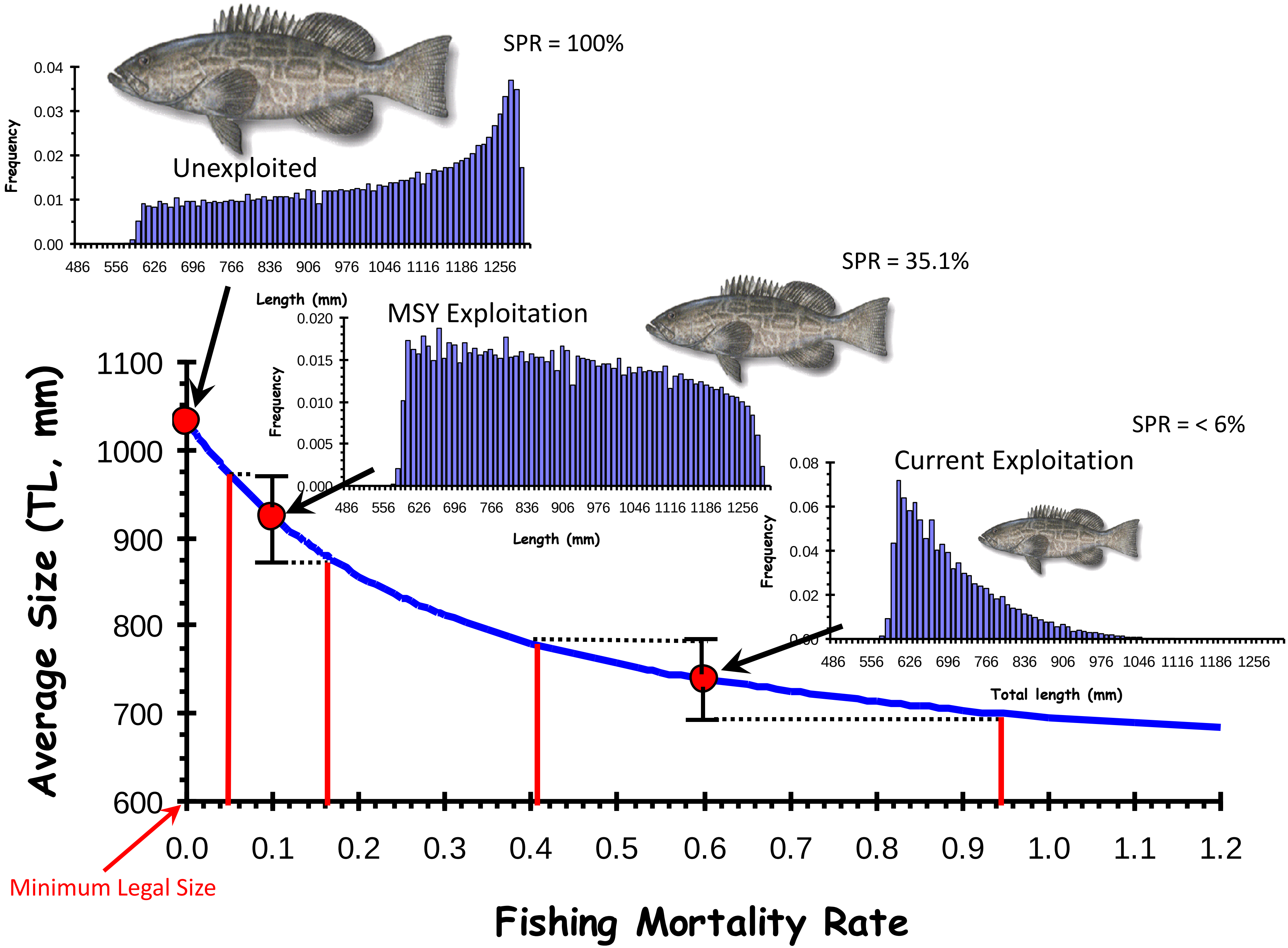
- Total morality (Z) from length models
- Need natural mortality (M) to obtain fishing mortality rates (F)
- Assume that only a small fraction (S) of a cohort is left at longevity (t-lambda) (Hewitt and Hoenig 2005)

$$M = \frac{-\ln(S)}{t_\lambda}$$



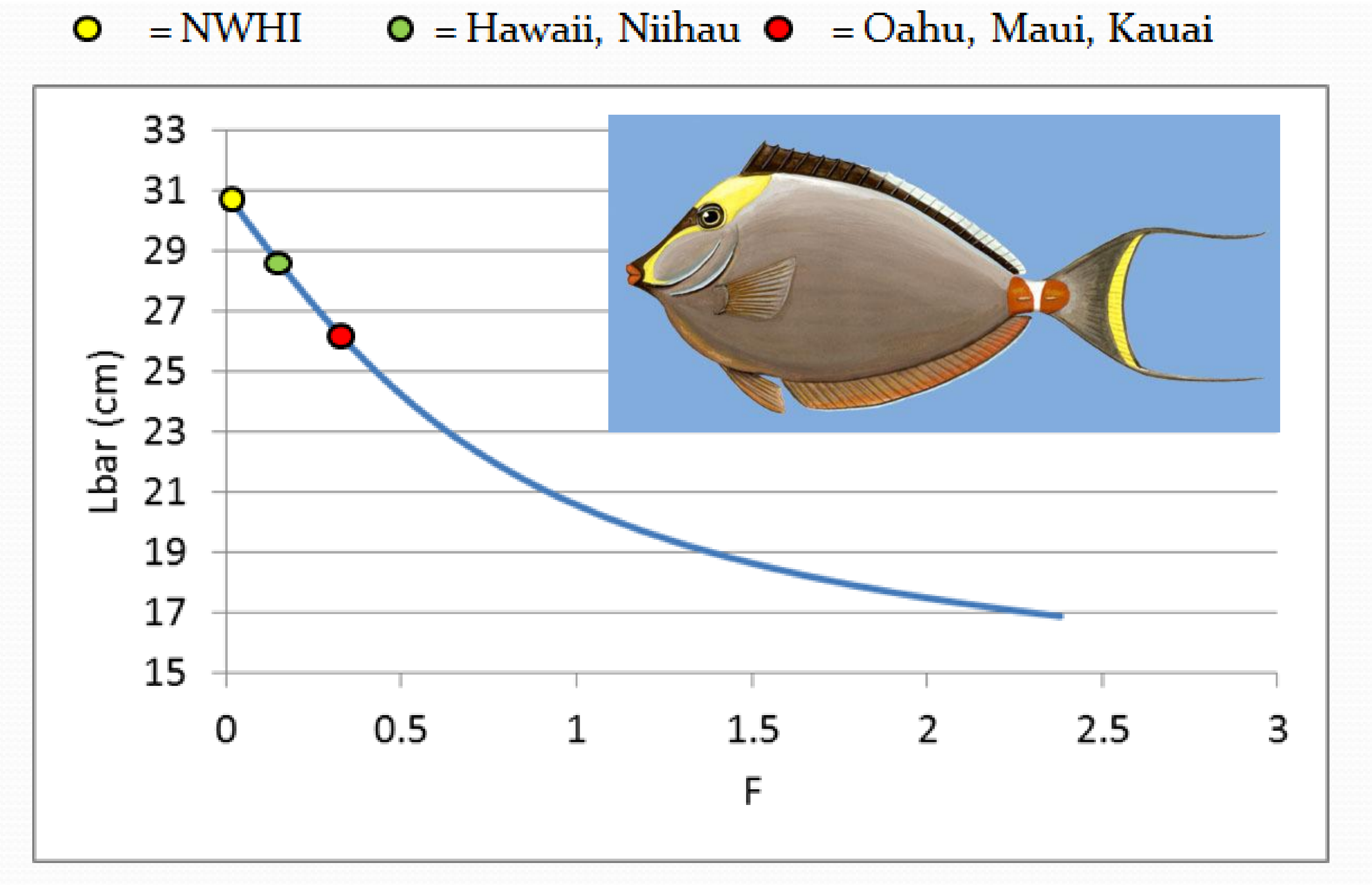
Longevity-based M vs. Pauly's empirical relationship



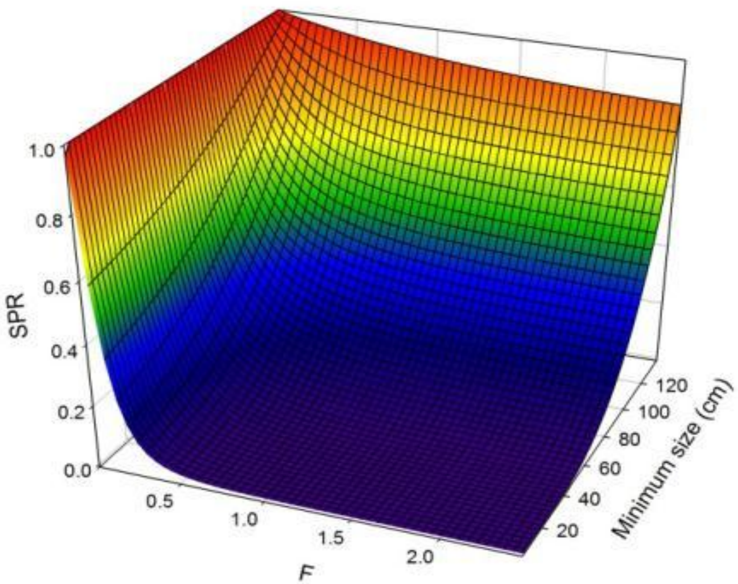


SPR = 100%
Unexploited
Frequency
Length (mm)
SPR = 35.1%
MSY Exploitation
SPR = < 6%
Current Exploitation
Total length (mm)
Average Size (TL, mm)
Fishing Mortality Rate
Minimum Legal Size

Hawaii example: orangespine unicornfish – *Naso lituratus*



Spawning potential ratio



$$N_t = R \cdot e^{-(M+F)t}$$

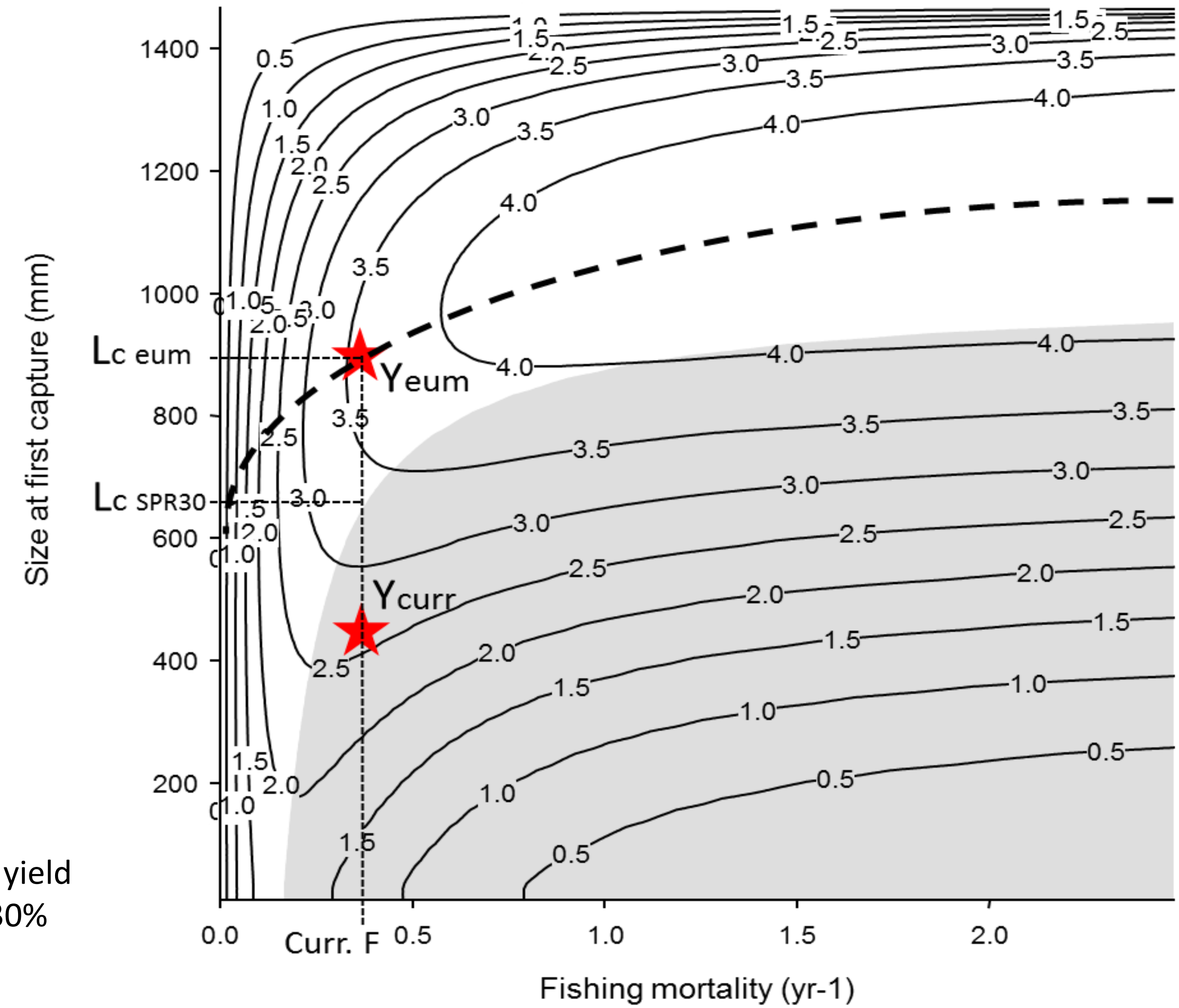
$$SSB = \sum_{a=a_m}^{a_\lambda} \overline{N}_a \cdot \overline{W}_a$$

$$W = a * L^b$$

$$L_t = L_\infty(1 - e^{-K(t-t_0)})$$

$$SPR = \frac{SSB_F}{SSB_{F=0}}$$

Yield-per-recruit



Lc eum = min. size to maximize yield
Lc SPR30 =min. size for SPR of 30%

Key model assumptions

1. Individual growth can be described by constant K and L_{inf} over time
2. Constant and continuous recruitment over time
3. Natural mortality rates are constant for all ages (or ages greater than t_c for F)
4. Mortality rates are constant over time
5. Population is in or close to equilibrium (i.e. sufficient time has elapsed for average length to represent current mortality levels)

Recruitment effects on Z (and F) estimate

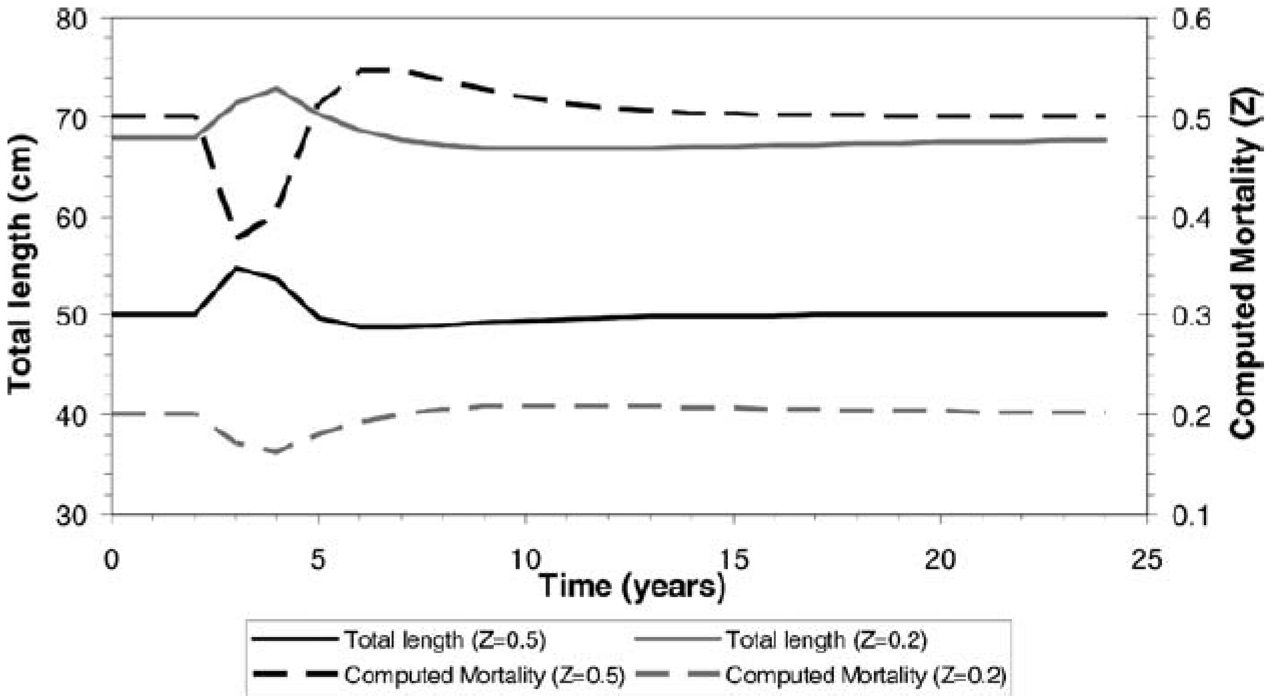


FIGURE 7.—Response of the Beverton–Holt length-based mortality (*Z*) estimator to a violation of the assumption of constant recruitment in goosefish. A complete reproductive failure under two different levels of fishing mortality is simulated in year 3. Life history parameters for goosefish in the southern management region (Middle Atlantic Bight) were used for this example.

Gedamke & Hoenig 2006

Recruitment effects on F estimate

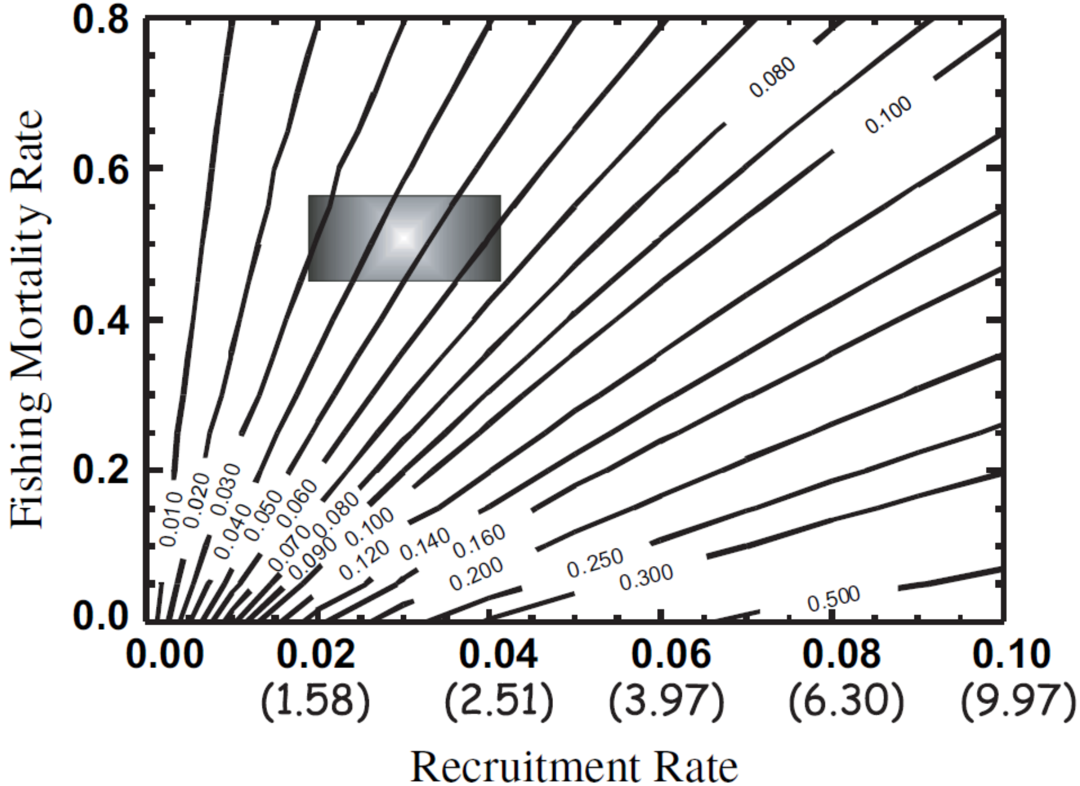


Figure 2. Contours of proportional bias in Lbar mortality estimates for hogfish at various annual rates of recruitment (r) and F (values in parenthesis: lifetime factor increase in recruitment corresponding to r).

Ault et al. (2005)

Equilibrium assumption

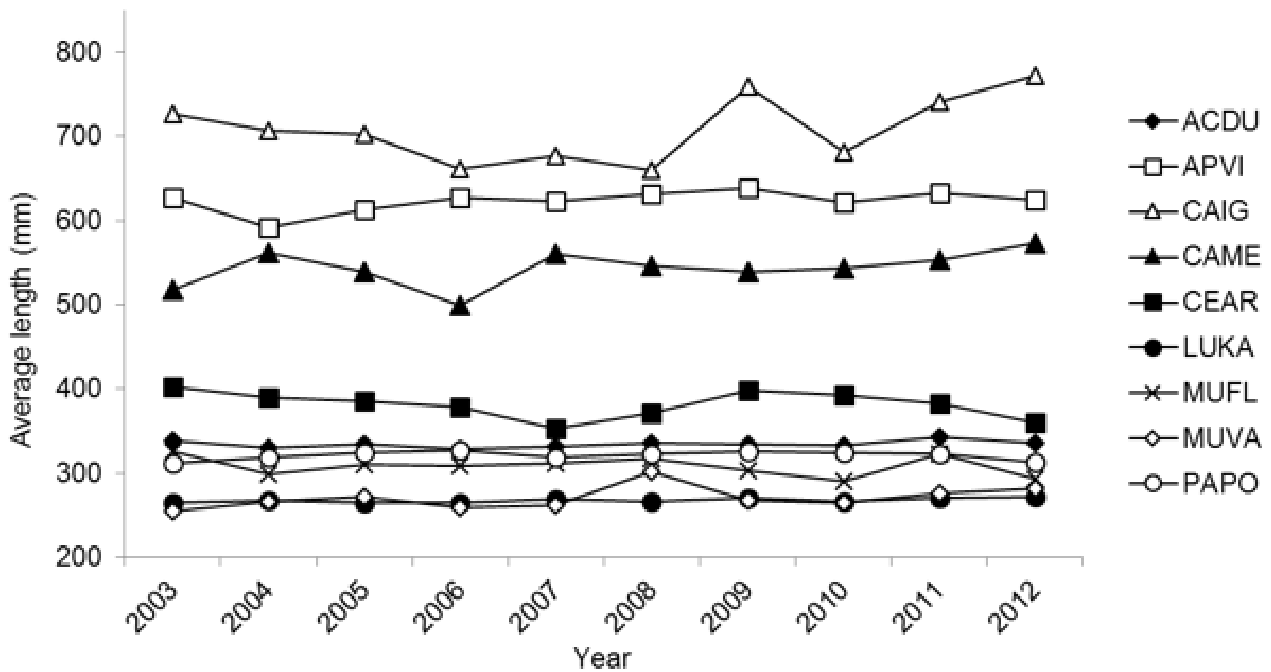


Figure 4 – Average lengths for 9 Hawaiian reef fish species in the MHI with marginally sufficient length observations (n>30 for every year) for an analysis of temporal trends from 2003 to 2012. Data from commercial fishery.

Non-equilibrium total mortality estimator

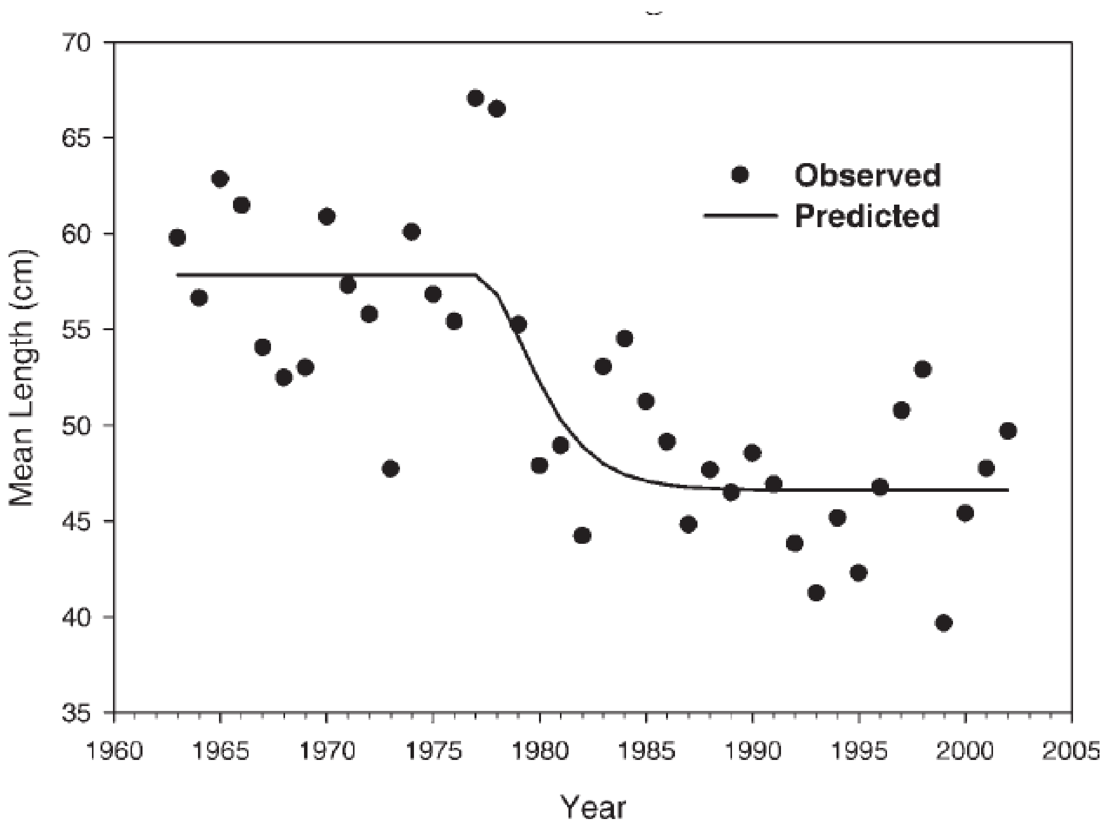
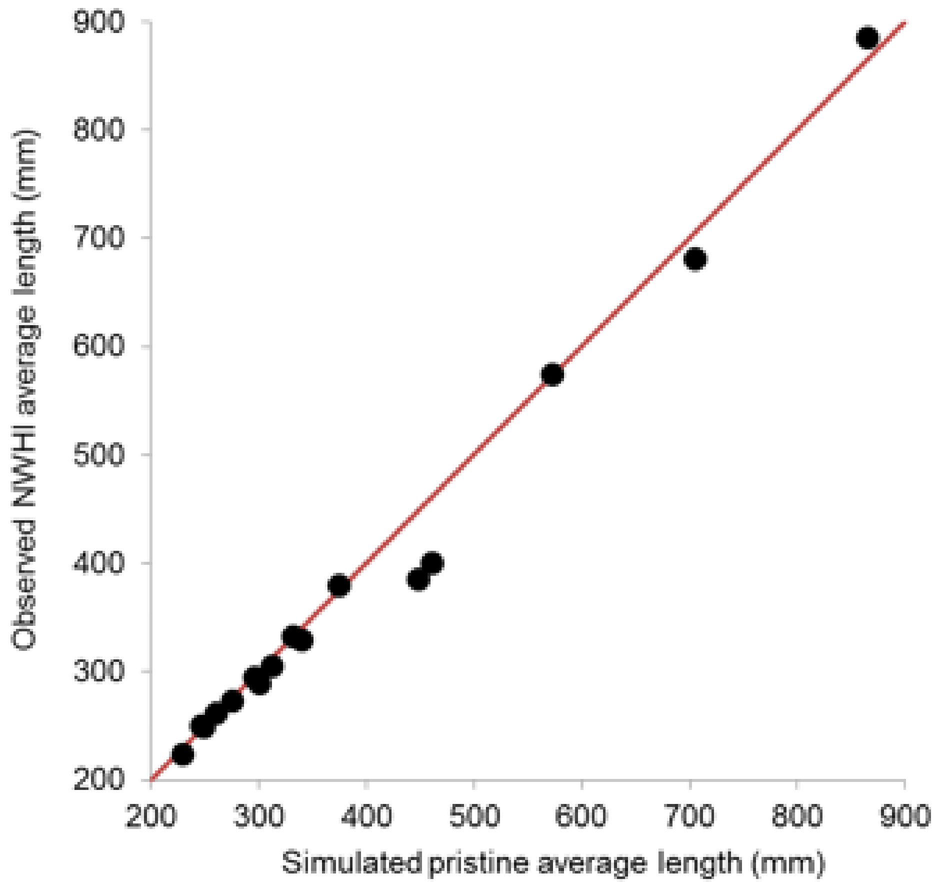


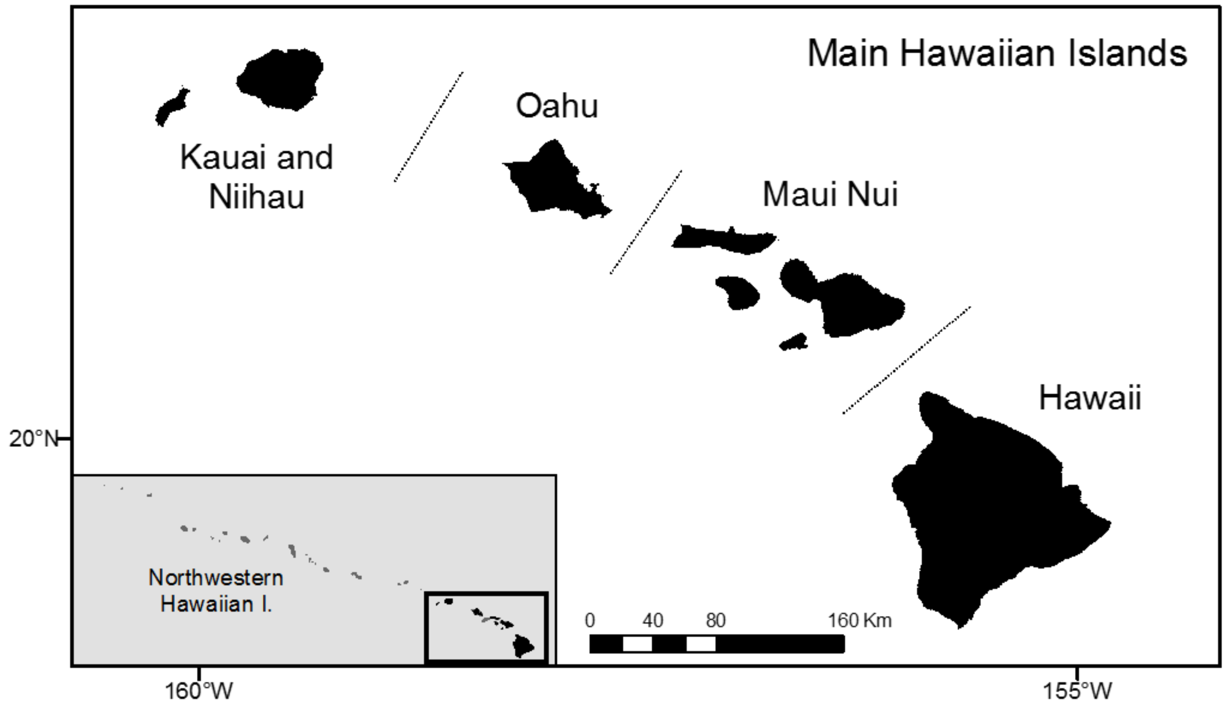
FIGURE 2.—Observed mean lengths of goosefish from the 1963–2002 National Marine Fisheries Service annual groundfish surveys in the southern management region (Middle Atlantic Bight) and predicted values from the transitional length statistic derived in this paper.

Gedamke and Hoenig (2006)

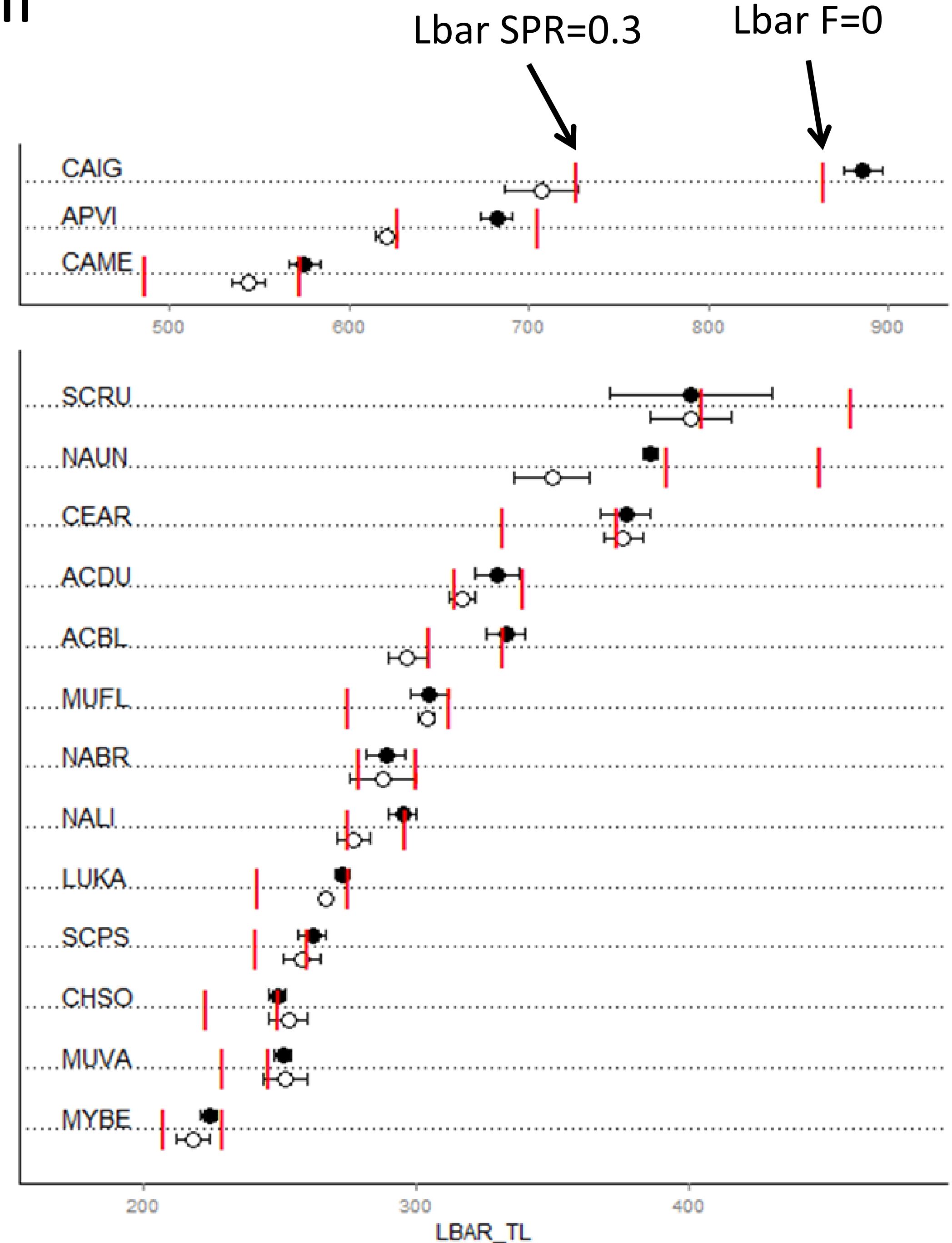
Verification of model and parameters



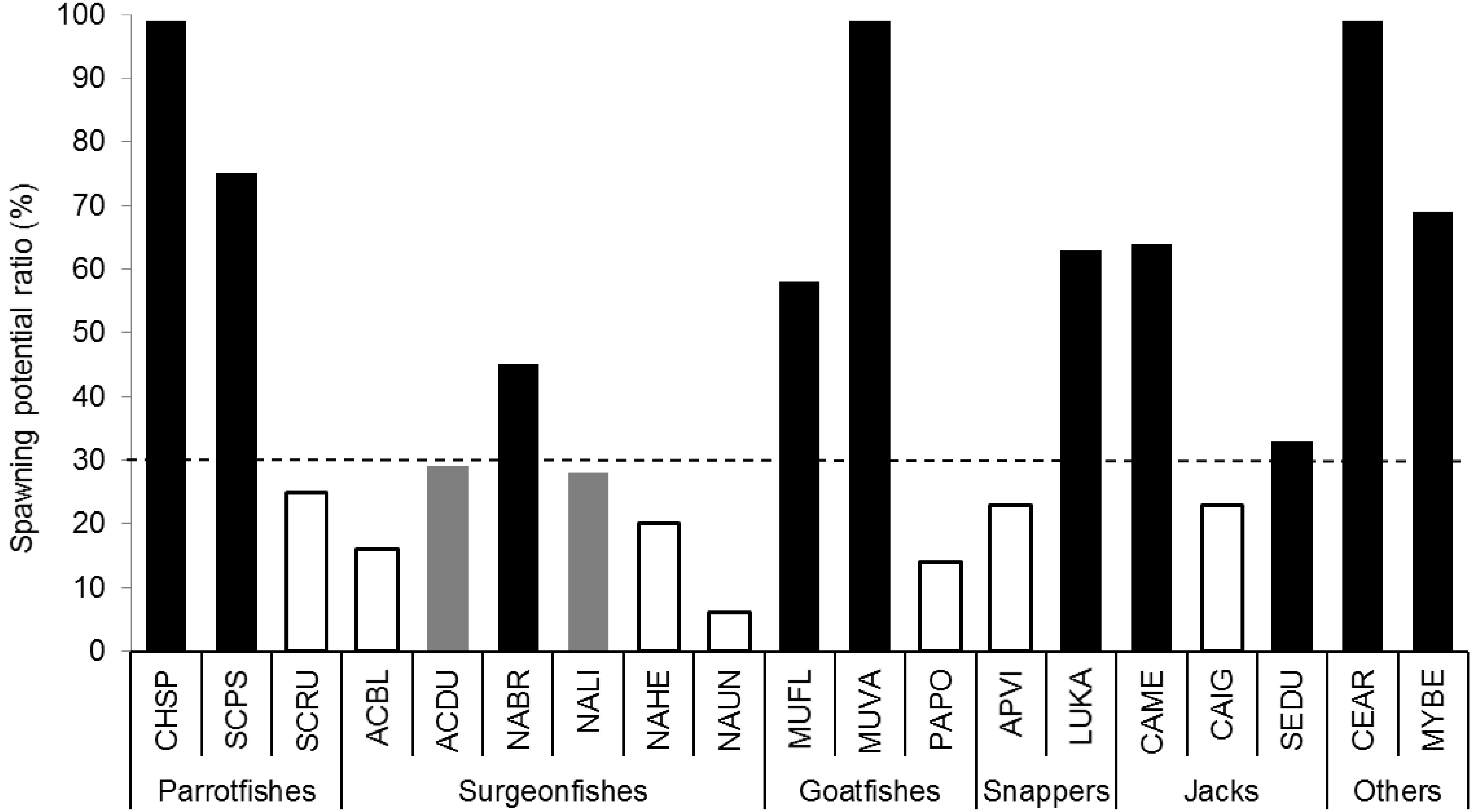
Example from Hawaii



Average lengths in Hawaii

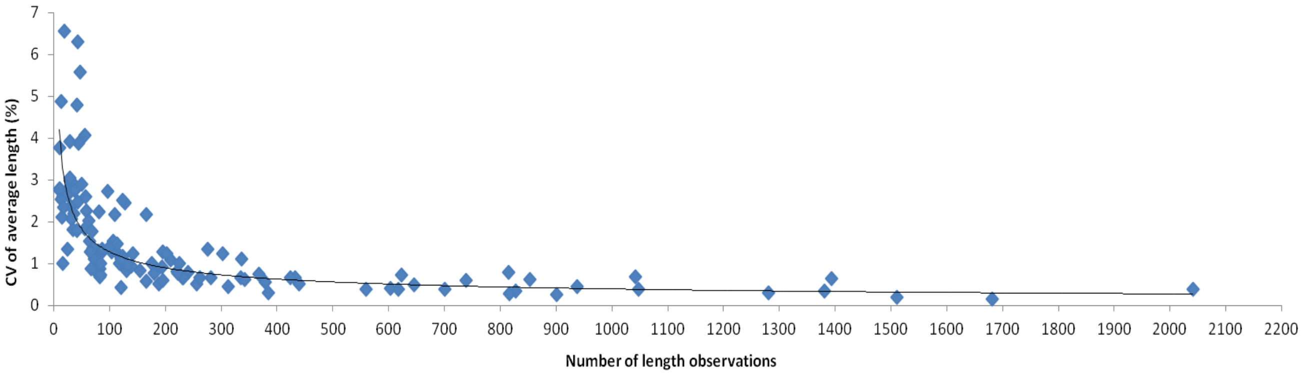


Spawning potential ratio in Hawaii



Data-poorest

- Good size structure data
- No information on life history



Life history information for the top 20 targeted species

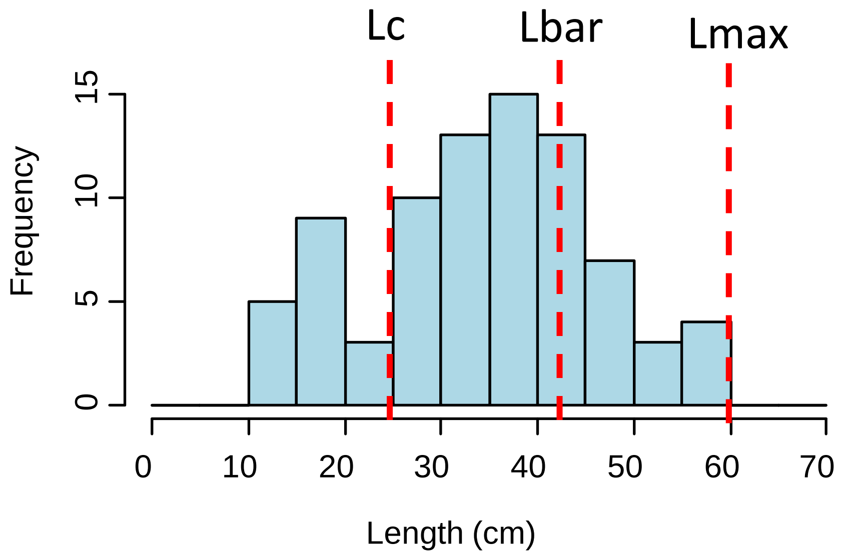
	Hawaii	Amer. Samoa	Mariana
No growth curve	40%	45%	15%
No growth curve from local studies	60%	85%	80%
No growth curve from in-depth local studies	90%	90%	90%

World-wide: 1200 of 7000 (Froese & Binohlan 2000)

What we know:

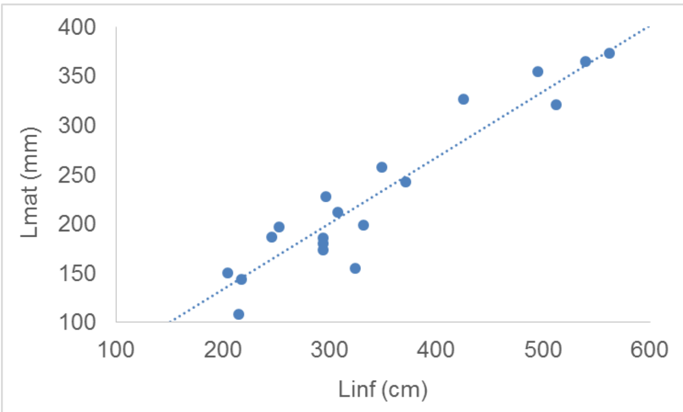
Spectacled parrotfish example

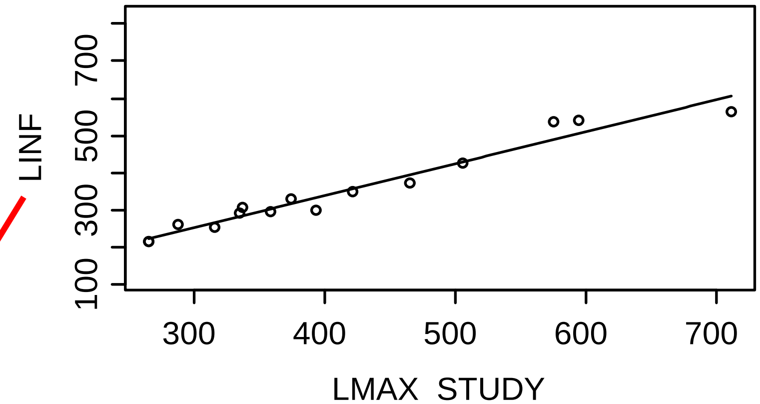
- Lc, Lbar, Lmax
- Family: Scaridae

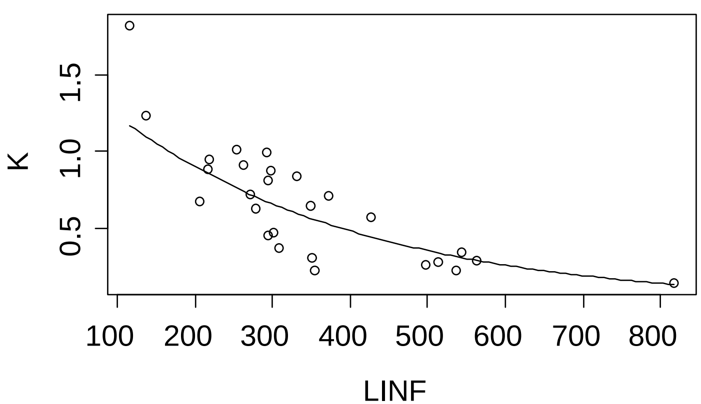


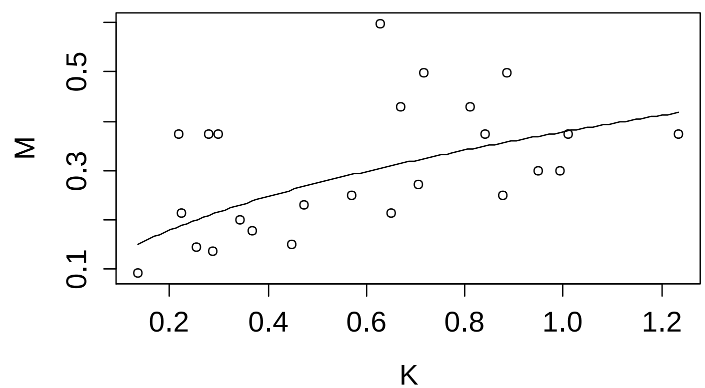
Using life history relationships to create multivariate probability distributions

Relationships for parrotfishes

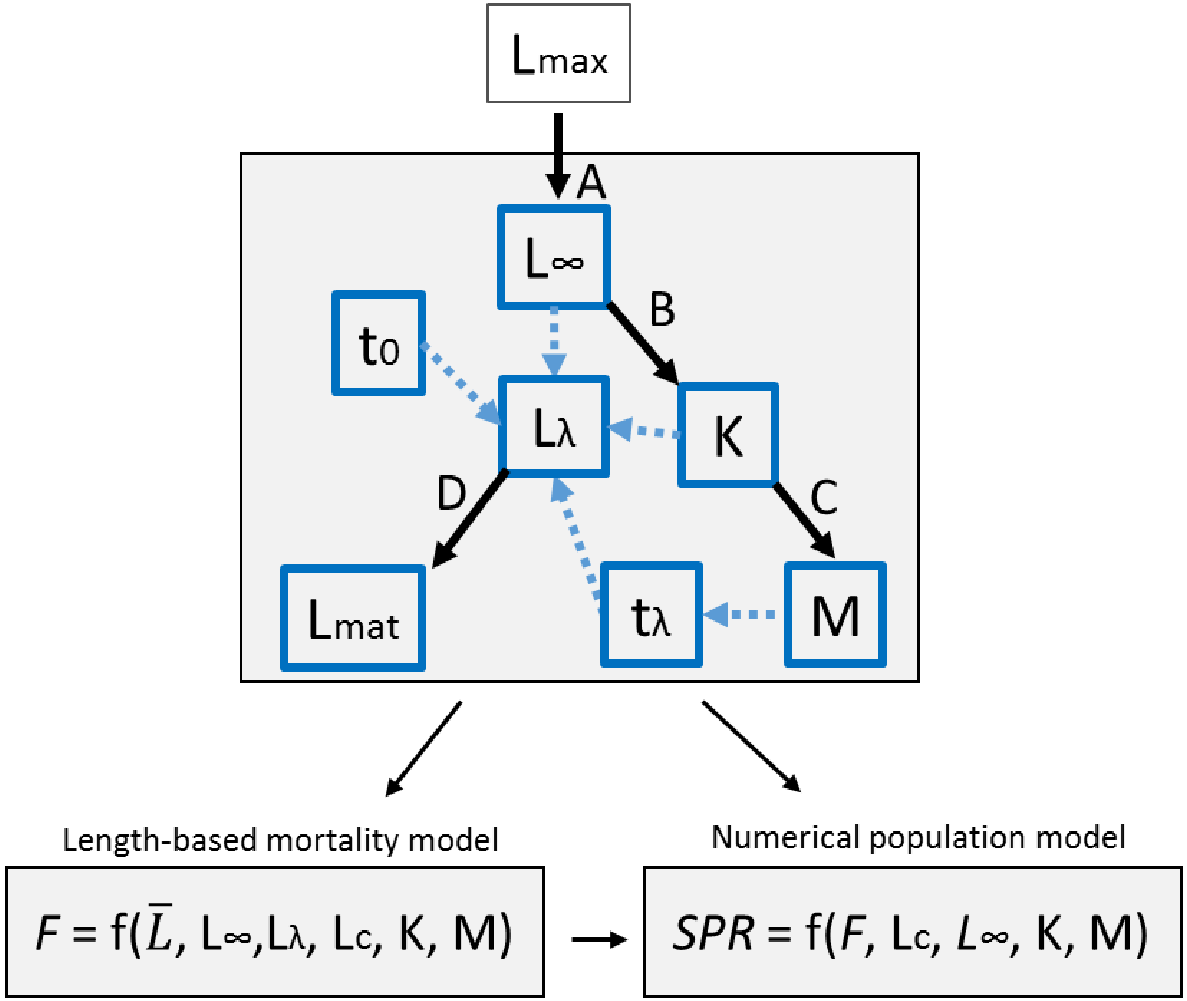






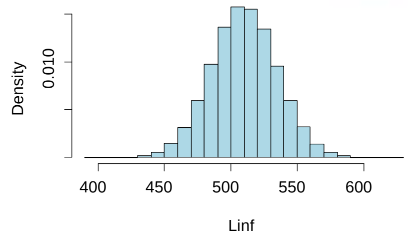


Using life history relationships to create multivariate probability distributions



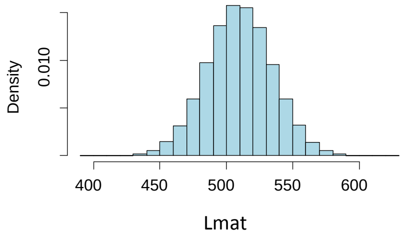
650 mm

Lmax



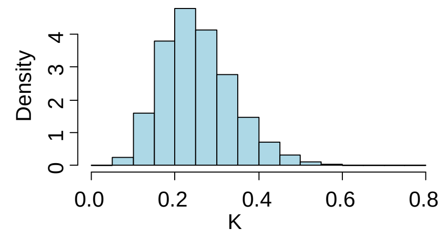
$$E = b_0 \cdot \text{Lmax}$$
$$L_\infty \sim \text{normal}(E, SD)$$

Linf



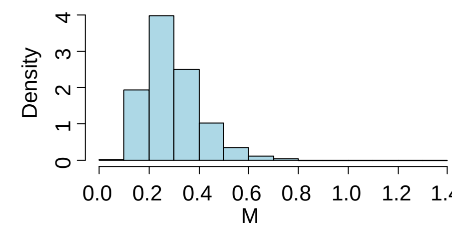
$$E = bo + b1 \cdot L_\infty$$
$$Lmat \sim \text{normal}(E, SD)$$

Lmat



$$E = b_0 \cdot \; e^{b_1 L_\infty}$$
$$K \sim \text{gamma}(\text{shape}, E/\text{shape})$$

K



$$E = b_0 \cdot \; K^{b_1}$$
$$K \sim \text{lognormal}(\log(E), \text{sdlog})$$

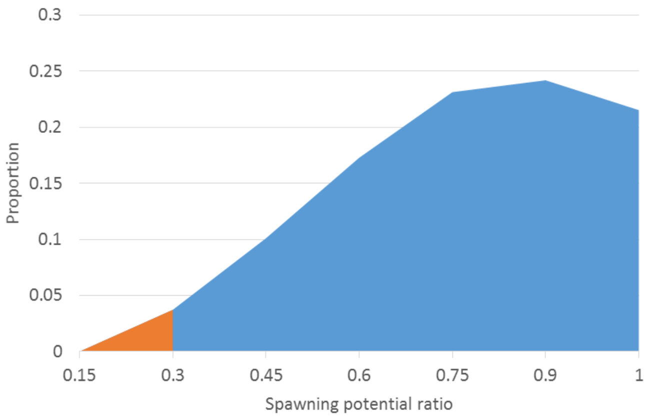
M

Life history multivariate distribution

Linf	K	T0	M	Lmat	Longevity
525.5991	0.2972	-0.7	0.3119	109.6687	9.604
570.4797	0.1668	-0.7	0.1318	105.4444	22.7253
550.6714	0.2874	-0.7	0.2247	250.4495	13.334
527.9909	0.399	-0.7	0.2478	343.7768	12.0874
497.3382	0.3431	-0.7	0.1579	119.6563	18.9725
553.9505	0.296	-0.7	0.3233	104.0076	9.2672
471.433	0.4092	-0.7	0.2806	194.6356	10.6757
516.9926	0.2832	-0.7	0.1441	75.831	20.7922
540.5398	0.3244	-0.7	0.273	150.5569	10.9744
495.4193	0.5381	-0.7	0.4184	199.0558	7.1599
502.3647	0.1975	-0.7	0.1993	156.3502	15.0331
506.0215	0.7913	-0.7	0.4031	126.8569	7.4322
526.8515	0.3946	-0.7	0.2433	63.6915	12.3108
509.1078	0.2262	-0.7	0.1919	119.7038	15.6075
538.6724	0.1965	-0.7	0.1651	81.5253	18.1482
488.1215	0.3136	-0.7	0.2669	210.2209	11.2247
530.9891	0.3421	-0.7	0.2241	115.7655	13.3663
497.6451	0.4577	-0.7	0.2264	144.6224	13.2334
488.4994	0.2498	-0.7	0.2622	184.6779	11.4259
514.3647	0.4249	-0.7	0.2982	141.5731	10.0464
539.2256	0.2114	-0.7	0.1797	157.9391	16.6713
508.685	0.2748	-0.7	0.1779	161.9648	16.8426
514.228	0.2821	-0.7	0.1975	140.4129	15.1647
517.7012	0.2791	-0.7	0.2404	83.1515	12.4599
508.5869	0.2496	-0.7	0.4017	244.9111	7.4567
468.0371	0.3153	-0.7	0.1521	183.6726	19.6959
511.619	0.2664	-0.7	0.1262	154.3247	23.7377
481.8875	0.2758	-0.7	0.2522	105.0302	11.8771
468.3386	0.4352	-0.7	0.2507	235.9846	11.9481
520.4963	0.5342	-0.7	0.1554	208.9957	19.2761
467.3158	0.6368	-0.7	0.2918	205.8328	10.268

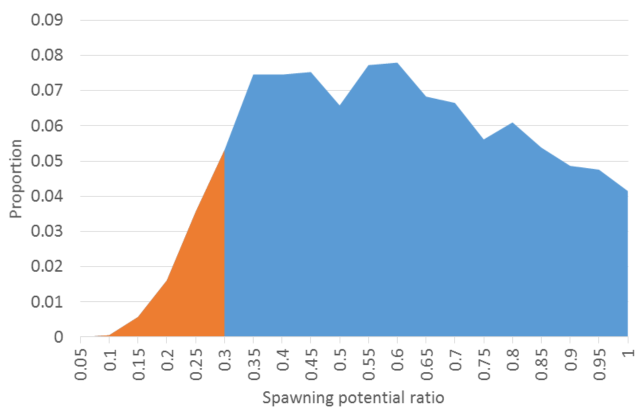
Monte Carlo outputs

Spectacled parrotfish example

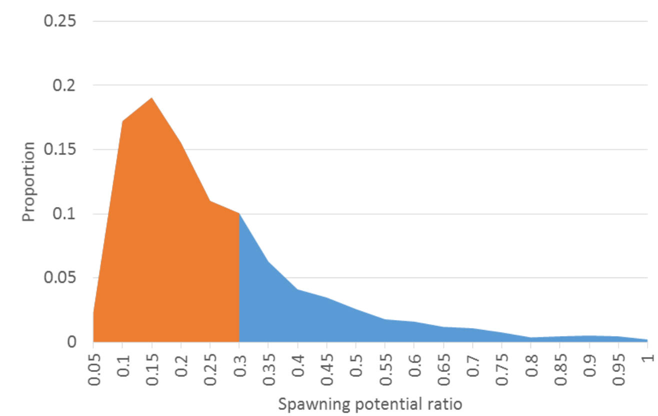


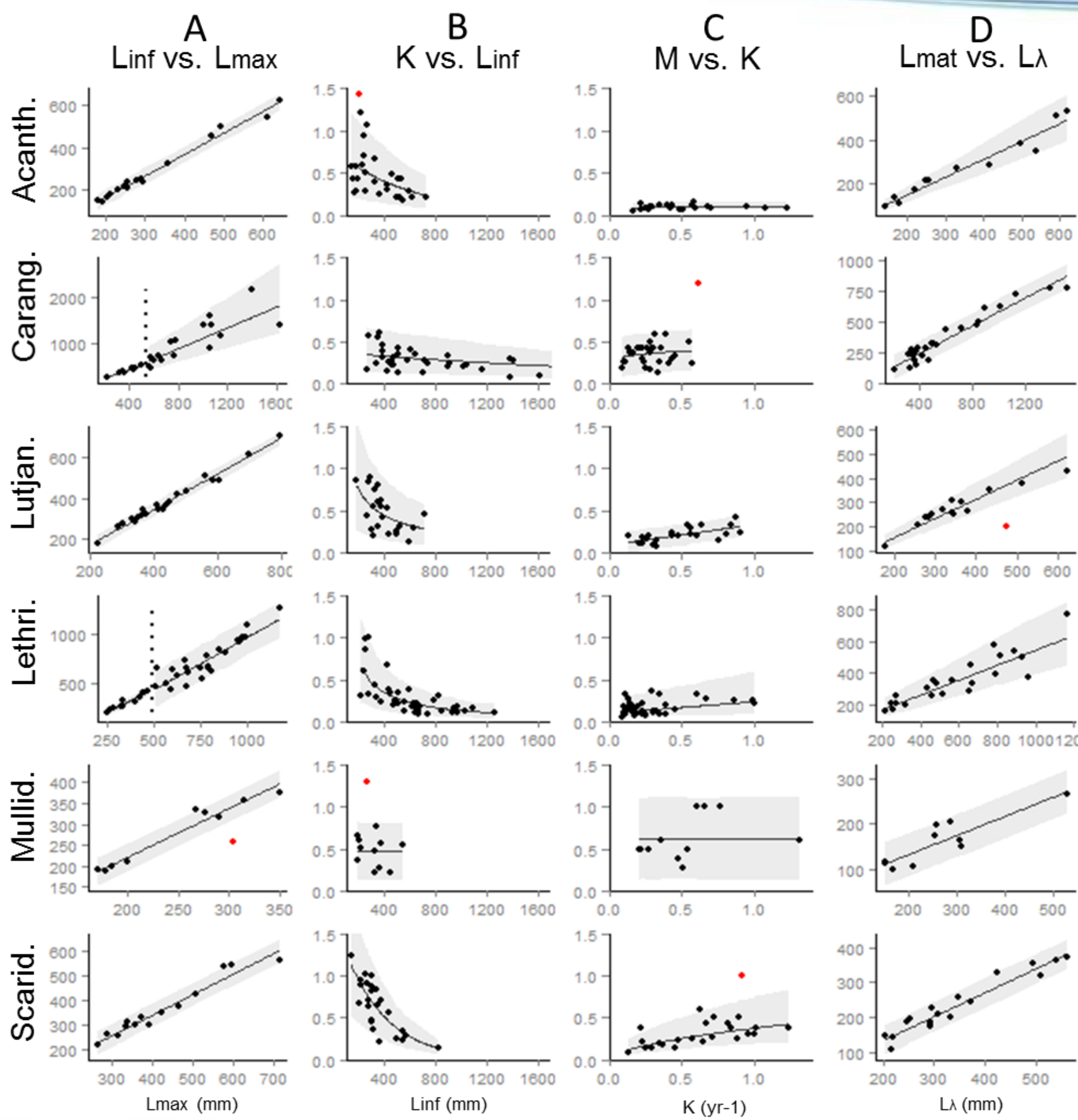
Lbar = 42 cm

Lbar = 40 cm



Lbar = 35 cm




A
Linf vs. Lmax
B
K vs. Linf
C
M vs. K
D
Lmat vs. Lλ
Acanth.
Carang.
Lutjan.
Lethri.
Mullid.
Scarid.
Lmax (mm)
Linf (mm)
K (yr-1)
Lλ (mm)

Summary

- Data-poorer situation (some life history info)
  - Growth curve (Linf, K, t0), length-at-maturity, and longevity obtained from literature (local or regional)
  - M derived from longevity
  - Truncated length-based Z model used to obtain F
  - Numerical population model used to derived SPR, yield, optimum Lc, etc.

Summary

- Data-poorest situation (no life history)
  - Linf, K, Length-at-maturity, and M all derived from Monte Carlo simulations based on family-specific empirical relationships and a starting Lmax value
  - Truncated length-based Z model used to obtain F distributions
  - Numerical population model used to derived SPR, yield, optimum Lc, etc. distributions

- Strengths
  - Low data requirements
  - Avoids relying on poor catch and effort data
- Weaknesses
  - Simple model with important assumptions
    - Constant mortality (F, M) with age
    - Relatively stable recruitment
    - Recruitment independent of spawner biomass

Next steps

- Model integration
  - ➢Datasets (biosampling, UVC, commercial)
  - ➢Catch, CPUE, population abundance estimates
- Integrating stock recruitment relationships

Increasing assessment tiers

- Size structure data
  - Combination of UVCs (i.e. diver surveys) with fisheries-dependent dataset is ideal
  - Biosampling of reef fish in Hawaii would help fill a gap in recreational fishing information and avoid relying on commercial dataset for length info
- Life history parameters
  - Major bottleneck in conducting more analyses
  - Send specimens to more labs, create local capacity